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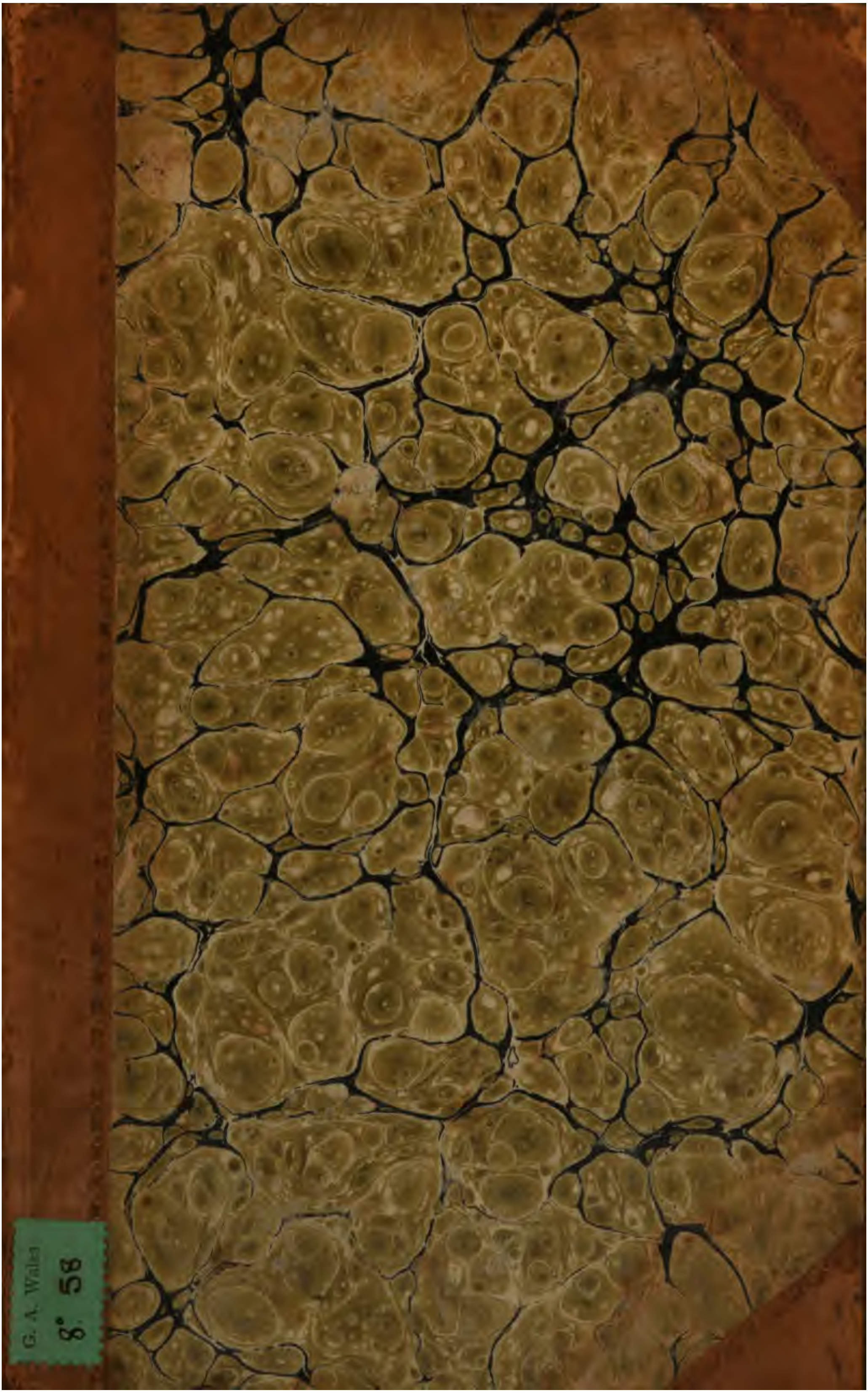

G. A. Wales
8°. 58

Gough
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8°. 58.

J. H. 1825

DESCRIPTION
OF THE
IRON BRIDGES OF SUSPENSION
NOW ERECTING
OVER THE STRAIT OF MENAÏ, AT BANGOR,
AND
OVER THE RIVER CONWAY, IN NORTH WALES;
WITH
TWO VIEWS:
ALSO SOME ACCOUNT OF THE
DIFFERENT BRIDGES OF SUSPENSION
IN ENGLAND AND SCOTLAND;
PARTICULARLY OF CAPTAIN S. BROWN'S IRON BAR BRIDGE OVER
THE RIVER TWEED.
WITH
Remarks on the proposed Suspension Bridge
OVER THE RIVER MERCY, AT RUNCORN GAP;
AND
SOME CALCULATIONS OF THE STRENGTH OF MALLEABLE IRON,
FOUNDED ON EXPERIMENTS.

BY T. G. CUMMING,
SURVEYOR.

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PREFACE.

A SIMPLE and economical principle of constructing bridges has lately been adopted, with success, in this country; which appears to be much superior to any other for wide spans, and peculiarly adapted for large navigable rivers. These advantages only require to be known, in order to be duly appreciated in a commercial nation, and, therefore, a considerable degree of interest has been manifested respecting the large works on this principle, which are now in progress; and also an account of the works already finished, is much desired. In this publication we propose to describe both the works in hand, and those which are completed; and also to notice the most extensive project of the kind that has yet been proposed. But as no popular illustration of the nature and advantages of the principle has yet appeared, perhaps a few remarks on the subject will be useful, previous to entering on the description of the Bridges.

In the common principle of construction, an arch, with its convex side upwards, constitutes the support of the bridge. The weight of the arch itself, and of the load it supports, tend to compress it into a flatter curve.

In the newly-adopted principle a chain constitutes the support of the bridge; it forms a curve like the arch, but the convex side of the curve is, of course, downwards; and the weight tends to draw the chain apart. Any material of a durable kind, that is capable of resisting great tension, is applicable to construct bridges of this kind, and they are appropriately called, *Suspension Bridges.*

The mere difference of employing the tensile power of a material, instead of its resistance to compression, does not, however, present any advantage; in fact, a greater force, per square inch, is required to crush wrought iron, than to draw it asunder; therefore, the real advantage of employing the principle of suspension still remains to be explained.

In the common bridge, where the weight tends to compress the arch; if that arch were made only of a small depth, a slight force would derange it, and once deranged in a certain degree, it would fall. Hence in a bridge of this kind, the arch must necessarily have a considerable depth to render it stable, and sufficiently firm for resisting the stress of a loaded waggon; but this increase of the depth of the arch, to give stability, also increases the load to be supported, and, consequently, a much greater quantity of material must be employed than is necessary to resist the pressure in the direction of the arch.

In a suspension bridge it is different, for to whatever degree the equilibrium of the chain be disturbed, it resumes its natural state as soon as the disturbing force ceases to operate. That is, it is endowed with the power of resisting any change of form by its arrangement, and no excess of material is necessary to preserve that arrangement. This is the chief advantage of a suspension bridge, and it is one of immense importance in the construction of bridges of large span.

The difference of the two principles, as far as regards stability, may be strikingly illustrated by models. A model, on the suspension principle, arranges itself as soon as suspended; one or the other principle requires considerable attention and delicacy of adjustment to rear it; and when it is reared a slight force destroys it. A force equally slight, in comparison to the weight and proportions of the structure, destroys a large bridge.

It was remarked, that the suspension bridge was easily put together in model; it is joined with comparative simplicity of means on the large scale; and hence only a small expense is necessary for scaffolding in its first erection, and scarcely any is required for repairs. But for a common bridge, on the principle of compression, a very strong and accurate centre is necessary to construct an arch upon; and the expense of centring and scaffolding is often greater than the whole expense of a suspension bridge for the same situation.

The expense of piers and abutments are also reduced, in a considerable degree, by adopting the suspension principle; and when it is necessary to found in a difficult situation, the design may be so arranged as to prevent the work being exposed to lateral pressure; besides allowing a greater latitude of choice for the places of the piers and abutments.

Neither is it unworthy of notice, that with a suspension bridge we can give an equally free space for the passage of vessels in every part of the width between the piers; for the roadway may be level, and all the space left clear between it and the water line; and hence it is better for a navigable river, than a common bridge where vessels are confined to the middle of the arch.

It will be evident from the nature of these advantages, "that the benefit of these useful structures might be extended to situations where at present it is unknown;" and the delay, trouble, and danger of a ferry might in many instances, be exchanged, at a moderate expense, for a safe, commodious, and permanent bridge.

The general principles of equilibrium and stress are the same in suspension as in other bridges; in ordinary cases the load is very nearly uniformly distributed over the length of the bridge; and consequently, the curve assumed by the suspending chains will be nearly the same as the parabola. The stress in the different parts of the chains may be more accurately computed by a formula in Tredgold's Carpentry, art. 61,—out for all practical purposes it will be sufficiently accurate to consider the curve a parabola, and compute them accordingly. The chains assume the form of the common catenary, only in the case where the roadway rests upon, and is of the same length as ths chains, which is a case of rare occurrence. Winch Bridge, across the Tees, is, however, one example. It appears to have been the common mistake of both scientific and practical men to imagine, that the curve assumed by the chains of a suspension bridge is, in all cases, the common catenary; and it has caused the one class to embarrass themselves in complicated and useless investigations; while the other have had occasion to express their surprise at " the liability of the catenarian curve to alter, when loaded in the direction of the horizontal plane of the connecting roadway."

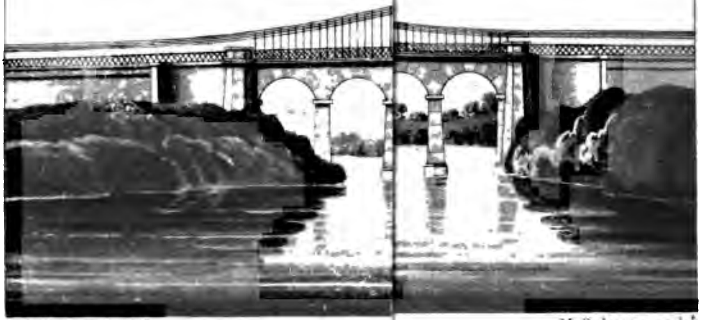
Other bridges have been erected, in which both the extending and compressing strains occur; as they do in the common drawbridge. The wire bridges of Galashiels and King's Meadows, in Scotland, are examples. In these the wires radiate from the points of suspension to equidistant points in the roadway. These radiating wires have to resist tension, while the sides of the roadway are compressed in the direction of the abutments. This mode of construction has some good properties; for each half of a bridge may be erected, independently of the other, and a portion to act as a drawbridge in the centre, might connect them as a roadway, or open as occasion required to give passage to masted vessels. On this principle we shall find no difficulty in extending a chain pier from one to two hundred feet over the sea, without being obliged to form a support at the extremity.

But for a continuous bridge, it is a more simple and easy method to employ chains collected into masses of the form of the curve of equilibrium; the same strength is gained with the same quantity of material; and the bridge forms a more chaste and beautiful object.

The material used for constructing the suspending chains of bridges in this country, is malleable iron. It requires a considerable degree of care to protect it from oxidation, and, therefore, cast-iron has lately been proposed as a more fit material for the purpose. (See Essay on Cast-Iron, p. 242. Second Ed.) It has the advantage of greater durability, and would be less expensive than malleable iron to obtain an equal degree of strength; while the additional weight from employing a greater mass of matter would render the bridge less liable to vibrate with small forces. We feel no hesitation in putting a cast-iron connecting rod to a powerful steam-engine, where the impulse at each stroke is much greater than the same rod would experience, if it formed one of the chain-bars in a suspension bridge; and when once cast-iron becomes introduced for these bridges, it will, on account of its durability, be universally employed in their construction.

Suspension bridges have been long known in various parts of the world; some were formed of ropes, and others of chains; but they remained rude and imperfect structures, formed without science, and executed only in places where the means were wanting to erect more substantial and useful bridges. The suspension bridge, the offspring of necessity, continued, therefore, unknown, or was smiled at as a humble make-shift, till a British engineer found it was capable of affording a fit and commodious passage for the mails of England across an arm of the sea.

Denbigh, 1824.



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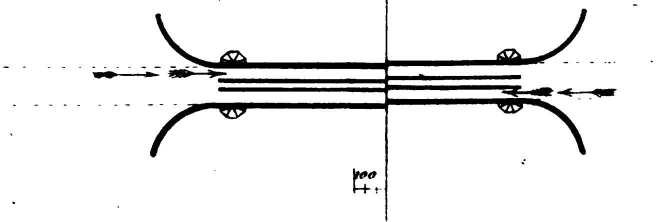

VIE

OF THE

MENAÏ BRIDGE,

NEAR BANGOR FERRY,

IN THE COUNTY OF CAERNARVON, NORTH WALES.

IN consequence of the union of Ireland with Great Britain, it has been a leading object with Government to facilitate the intercourse between the capitals of the two countries. In the year 1810, the House of Commons appointed a select committee "to inquire into the state of the roads from Holyhead to London, and the regulations for the conveyance of the mail, passengers, and merchandise, between Dublin and Holyhead." This committee recommended various measures for the improvement of the roads on this great line of communication, but in regard to expedition it would have been of little avail to have improved the roads, without remedying the delay and inconvenience, as well as danger in crossing the Menaï Strait.

In the years 1810 and 1811, several plans of bridges were proposed for effecting a regular and unobstructed passage in the place of the present ferry of Bangor, by Mr. Rennie and other architects, all of which were to be composed, principally, of cast-iron, with arches of sufficient span and height not to obstruct the navigation: one of the designs deliverered in by Mr. Rennie was for a bridge of cast-iron, having three arches, and the rest of stone, at Ynys y Moch, the centre iron arch to be of four hundred and fifty feet span, and the side arches one hundred and eighty.

Another design of Mr. Rennie was, for a bridge over the Menaï at Swelly Rocks, consisting of three cast-iron arches, and two stone arches; the centre arch of iron and three hundred and fifty feet span, with its crown one hundred and fifty feet above the high-water line of an ordinary spring-tide; at each end of this a stone arch of one hundred feet span; and again an iron arch of three hundred feet on each side of the stone ones. The three iron and two stone arches would thereby span the whole of what may be called the channels of the Menaï with land arches of stone on each side. The estimated expense of the former was 268,500*l.* and of the latter 290,417*l.* Two other designs were also delivered in by Mr. Rennie; but the one approved by the committee, after due investigation, was one of a single arch of cast iron, of five hundred feet span, with the crown of the arch one hundred feet above the level of high water-mark. This arch was projected by Mr. Telford; and, although the least expensive of any cast-iron bridge of those dimensions, the estimated cost of this bridge was upwards of 127,000*l.* But the construction of such a bridge presented a great difficulty, as fixing the proper centring could not be accomplished from below by ordinary means, owing to the rocky bottom of the channel, and the depth and rapidity of the tide-way. Mr. Telford was, therefore, led to devise a new mode of suspending the centring from above, and furnished a design for this purpose, which was laid before the commissioners for the improvement of the Holyhead road. This idea of suspending the centring appears, at least, to have led to the proposal of a suspension bridge, which was approved of by a select committee of the House of Commons (see the Third Report from the Select Committee on the Road from London to Holyhead, &c. 29 Ap. 1819), who, before they recommended to Parliament the execution of this bridge, called before them and examined Mr. Donkin and Mr. Rennie, civil engineers, and Mr. Barlow, of the Royal Military Academy, who had made experiments and calculations on the strength of materials. The construction of such a bridge, in the situation proposed, not being deemed injurious to the navigation of the Menaï; and a report being made to Parliament, the necessary funds were granted, and the work was soon after commenced at Ynys y Moch, on the Anglesea shore. The bridge consists of one opening of five hundred and sixty feet, between the points of suspension, and 100 feet in height between the high-water line and the lower side of the road-way; and the road-way being horizontal this height is uninterrupted for the whole 500 feet between the piers, except where the natural rock (which forms the western abutment) now interposes. But in addition to these 500 feet, there are to be four arches on the western side, and three on the eastern of the main opening, each fifty feet span, composed of stone, making in all 850 feet of opening. The drawing shows, that in regard to the navigation it is far preferable to any bridge of an arched form, as the latter affords the full height of 100 feet (only in the middle); while the former, as has been shown, affords the same full height for the whole 500 feet, which will be a considerable advantage to vessels passing the Menaï Strait, allowing them to stand closer to either shore while passing under the bridge. In regard to a saving of expense, this bridge, on the principle of suspension, has equally the advantage, the estimated expense being 70,000*l*. only; whereas the cheapest of the arched form, made of cast iron, would have cost nearly double the money. The road-way will consist of two carriage ways, each twelve feet in breadth, with a foot path of four feet between them, so that the platform will be about thirty feet in breadth: the whole will be suspended from four lines of strong cables of malleable iron, by perpendicular iron rods placed five feet apart, and these rods will support the road-way framing. The suspending power is calculated at 2016 tons, and the weight to be suspended, exclusive of the cables, at 342 tons, leaving a disposable power of 1674 tons. The four sides of the road-ways will be made of framed iron work, firmly bound together, for seven feet in height, and there will be a similar work for five feet below the cables: the weight of the whole bridge, between the points of suspension, will be 489 tons. It is calculated that the contraction and expansion of the iron cables may occasion a rise or fall to the extent of four or five inches; but the variations of the temperature of the atmosphere will not derange the bridge. The abutments will consist of stone work, as represented in the drawing; each of the two piers will be sixty feet by forty-two and a half wide, at high-water mark, having a foundation of rock. Those piers (connected with the whole of the remainder of the masonry) will form a mass constructed with blocks of hard limestone, of much greater weight than is necessary for supporting a bridge of this kind. Two main pillars, or piers, will also be constructed of the most substantial masonry, for the purpose of raising the cables from which the bridge is to be suspended. As the cables will be carried over the top of these pyramids, so as to form nearly similar angles on each side, the pressure will be almost perpendicular.

Mr. Telford proposes to have four lines of suspension in the breadth of the bridge, and in each line four cables, making in the whole sixteen; these cables will pass over rollers fixed on the summit of the pyramids, and be fastened at the extremities to an iron frame, lying horizontally over the top of the small arches, and under a mass of masonry. From these cables the roadway will be suspended by vertical iron rods, connected at their lower extremities with wrought iron bars, both tranversely and longitudinally; thus forming a frame on which timber will be laid for the road-way. The distance of five feet is kept between the rods, in order that the suspending power may be equally distributed throughout the whole length of the bridge. The suspending rods will pass between the cables, and depend upon each two of them, so that the general strength of the bridge could not materially be affected by taking one away.

The cables and the flooring, as well as the suspending rods, will be constructed and united in such a manner, that each of the parts may be taken out and replaced separately; so that there can be no difficulty in repairing any part of the bridge whenever required. A temporary wire bridge was proposed to be made, from one abutment to the other, in order to carry over the cables, and arrange the several parts of the bridge while building; but it is now understood that the cables will be raised from barges moored across the channel.

The length or distance between the piers is 500 feet, and the greatest deflection thirty feet, which will require the length of the cable to be 505 feet, and the weight of 505 feet of a square inch rod will be about 1704 lbs. which will produce a strain on each point of suspension of 3632 lbs. The strain necessary to produce a fracture on the same rod is twenty-seven tons, or 60,480 lbs.; such a bar would therefore bear a load (including its own weight) of 28,372 lbs. to be uniformly distributed over it before a fracture would take place. This weight multiplied by the number of square inches in the section of all the bars will give the extreme weight the bridge would support, or rather the least weight that would break it. Suppose four cables, each of fifteen inches area, or sixty inches section on the four, therefore 28,372 × 60 = 1,702,320 lbs. or 760 tons, is the whole weight the bridge would be just able to support.

Mr. Telford, in his evidence before the Select Committee, as given in their Report, says, the distance between the points of suspension being 560 feet, and the versed sine thirty-seven feet, or about one-fifteenth of the chord line; by calculation I find, that the weight to be suspended is 342 tons; and by numerous experiments made to ascertain the strength of malleable iron, it appears, that with a chord line of 560 feet, and a versed sine of thirty-seven, a good bar of iron one inch square, will (besides its own weight) carry ten tons and a half, and about one half that weight, before it begins to stretch (permanently). The Menaï bridge contains a section of 192 square inches, which, at five and a quarter tons to each square inch, will support 1008 tons, being a surplus of 666 tons above the real weight of the bridge; and there would be required a further weight of 1008 tons to break down the bridge, which may be deemed more than sufficient against any probable trial to which the bridge can be exposed. The cables passing over the stone piers constructed of the most solid masonry, will then pass down to the cast-iron frame before described, thereby embracing the whole mass of masonry and spandrils, making in all about 12,000 tons at each end of the bridge, exclusive of the great pyramids. The weight of the bridge between the points of suspension, including cables, being only 489 tons, there is not much reason to expect undulation, from any weight which will be laid on any particular part; but to guard against any effect of that sort, four sides of the road-ways, of framed iron-work firmly bound together for seven feet in height, and similar work for five feet in depth below the cables, which, when they meet together in the centre of the bridge, will constitute a framework twelve feet deep, with a bridge of thirty feet in breadth, and 532 in length, there is not much to be apprehended from side vibration; but in order to provide against this possibility, two horizontal cables crossing the bridge diagonally, each of which laying hold of the middle of its length, and passing round a cast-iron frame projecting from the opposite sides of the great pyramids, and from thence carried to the masonry of the abutments; thus creating a diagonal stay upon seventy feet in breadth.

When we consider the magnitude and strength of the piers, and the resistance to crush which the stones possess, of which they are formed, there can be no doubt of the sufficiency of these stupendous piles of masonry, over which the cables will pass; these cables being continued to the cast iron frames which connect the masonry of the abutments. The weight of the bridge is 489 tons; upon which, if 300 tons are placed, they make 789 tons: the pull of this weight at the abutments, upon a curvature of 1-15th, is found by experiment, over a pulley with a perpendicular weight, equal to about two and half times the weight of the other side, or 1972 tons; to counteract this, the cables are continued at nearly the same angles as those of the bridge, to the cast iron frame, which embraces about 12,000 tons of masonry; and to which much more, if necessary, might be connected.

With regard to the contraction or expansion, with a difference of temperature of ninety degrees of Fahrenheit, the difference of length of iron would only be about five inches upon seven hundred feet; and the iron work being put up at the mean temperature, the contraction would be two and half inches, and the expansion the same, which could not derange the bridge. But if the main suspending cables were covered with some substance, which is an imperfect conductor of heat (and which is intended), the above variation of ninety degrees could not take place.

The cables are to be formed of a number of straight half-inch bars, connected at different lengths. On the square sides of these bars will be laid segments of circles, of a proper size for making the cables of a cylindrical form; the bars as well as segments to be joined longitudinally to the whole of the required length, and secured by bucklings every five feet, and then enveloped in flannel, well saturated with a composition of rosin and bees' wax, to preserve them from the weather, and the whole to be encircled with wire. The weight of each separate cable, from the points of suspension, is nine tons and three quarters, or 117 lbs. per yard. The weight of a drove of oxen is calculated at about 300 tons, supposing them to amount to 200 head, all closely huddled together, and the estimated weight necessary to tear the cables asunder is upwards of 2000 tons, which is about four times the weight of the entire bridge. The passing of a mail coach over the bridge is not expected to produce any undulation, or sensible perpendicular vibration; nor is any lateral vibration apprehended from the most violent gale of wind, by reason of the proportion that the breadth of the bridge bears as a frame to its extreme length.

From experiments made, it appears, that to separate a square of one inch and five sixteenths, of good malleable iron, required the weight of forty-eight. tons; and it required forty-three and half tons to break a bar of one inch and three ninths in diameter. Some bars of one inch diameter, and a foot long, stretched nearly three inches before they broke; and bars of three feet long, and one inch square, sometimes lengthened as much as eight inches before they gave way. Iron has this peculiar property, that a certain weight extends the length of the bar; after standing some time, the bar remains of that length, and it requires an additional weight to give it an additional stretch. Half inch bars, of tolerably good iron, will bear from six tons to six tons and a half; but they will elongate permanently at not much more than half that stress. It is a curious fact, and deserving the attention of philosophers, that frequently, at the moment of rupture, the bar acquires such a degree of heat in the fractured part, as scarcely to be grasped in the hand without the sensation of burning.

From numerous experiments, made by our ablest engineers, mighty as this undertaking appears, full confidence is placed in its practicability; and the public stand greatly indebted to the extraordinary industry and talents of Mr. Telford, for having contrived a plan, on a secure principle, for executing this stupendous work, for the sum of 70,000*l.*; and it is expected that the bridge may be completed in five years from the time of its commencement.

The foundation of the abutments, on both shores, is on a solid rock. The stone, of which the masonry of the piers is constructed, is procured on the north-east end of the Isle of Anglesea, from the estate of Lord Bulkeley, where the cliffs are nearly one hundred feet high; it is fine grey marble, perfectly solid, and in large masses, lying very conveniently close to the sea shore, where it is loaded into vessels and carried through Beaumaris Bay. From the narrowness of the channel of Menaï Straits, the tide runs through it with considerable rapidity; its velocity at high water, and high springs, is about four miles per hour; and occasionally rises twenty-five feet, but the general average is twenty *. The motion of the current is much obstructed by numerous rocks; vessels are obliged to pass at that time, when the current is strong, to carry them through their respective channels with safety; and, what is very uncommon, it is high water here, at full and change of moon, at nine o'clock in the

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* In the centre of the channel there are twenty-seven feet water, at low-water mark.

morning, on the Bar of Caernarvon; and about half past ten at Beaumaris. The tides set in from the western ocean, and are divided by the Isle of Anglesea: the tides divide about Plas Newyd, and flow about five hours, and ebb about seven. At the Swelly Rocks, north-east winds create great agitation in the water here. A wooden bridge was proposed, but objected to by many as impracticable; there were also great objections to a stone bridge, as the expense would be incalculable. The beach, on the Caernarvonshire side, rises gradually for the distance of about two hundred feet, when there is a perpendicular face of clay, with strata of rock about thirty feet high, and above this the ascent is very steep. The Anglesea shore is entirely rock, and the ascent very steep; but the rock continues for only a short distance from the shore, when it descends suddenly to nearly the level of high-water mark, after which it rises gradually towards the centre of the island. The Menaï here, although bearing the appearance of a river, is an arm of the sea, and of most dangerous navigation at some periods of the tide, particularly in boisterous weather; during the flood it is exceedingly dangerous. There are no less than six ferries within the space of fifteen miles, but the principal one is at Bangor; it is the narrowest part of the Strait, being about half a mile wide: over this the mails and passengers pass on their route to and from Holyhead, and near which the present stupendous structure is now building. It is thought by many, that the Island of Anglesea was once connected with the main land, as evident traces of an isthmus are discernible near Porthaeth-hwy; a dangerous line of rocks, nearly crossing the channel, which, on the flowing of the tide causes such eddies, that the contending currents of the Menaï seem to struggle for superiority. By the division of the bridge into two carriage-ways and a foot-path, there can be no confusion or danger from carriages, cattle, or persons meeting, as carriages going in one direction will take one side, and those passing the contrary way the other; whilst the pedestrian will be secured by a strong iron railing on each side, so that neither cattle nor carriages can come near him. The first stone of this magnificent structure was laid on the 10th August 1819, without any ceremony, by the resident engineer, Mr. Provis; and it is but justice to Mr. Telford to say, that whether we regard this bridge as affording a safe and commodious communication between the shores of the Strait, or in a general point of view, as applying a new principle in bridge-building, to the crossing of wide and deep rivers, ravines, and places where bridges on any other construction are totally impracticable; he equally deserves his country's thanks; the design is bold and magnificent, and, when finished, will be a lasting memorial to the talents and fame of the engineer.

Having concluded my observations on this stupendous work of art, I trust it will not be deemed an unpardonable digression, if I devote a few lines to the bold and romantic scenery, that presented itself on my road to Conway; for, while we pay every just tribute and respect to art, bountiful nature must not be forgotten.

The banks of the Menaï afford the most varied and beautiful scenery; the rich and luxuriant, the wild and romantic, alternately present themselves; ancient seats of Druidical superstition, with here and there an elegant villa, decorate its banks. *Plas Newydd*, the fine mansion of the Marquis of Anglesea, Baron Hill, late Viscount Bulkeley, and many others; the ocean, bounded only by the sky, finishing a scene truly magnificent. The white wave is seen tumbling round the distant rock, the craggy head of enormous *Pen-maen Mawr*, the huge peninsula of the two Ormes Head, and the steep circular Island of Priest Holme, or Puffin Island, the neat little town of Bangor and its surrounding romantic scenery, produce a pleasing effect. The cathedral and deanery are both humble unostentatious buildings, and well suited to the quiet, peaceful, and highly picturesque scenery around them.

Pursuing the turnpike road to Conway, the sublime mountains of Caermarthenshire bound the view to the southward: at the distance of about two miles, we pass the park and castle of Penrhyn, late the seat of the Peer of that name, but now of his much esteemed relative Mr. Pennant. The edifice is ancient, but has (not many years ago) undergone considerable reparation, under the direction of Mr. L. Wyatt, who has tastefully preserved (in his improvements) the characteristic style of the military Gothic. The present proprietor is making great and characteristic additions, particularly an elegant entrance to the Park. About a mile south of the castle, on an elevation that overlooks the river Ogwen, stands the little church of Llandegai, built about the time of Edward the Third. The enormous promontory, *Pen-maen Mawr*, too, presents itself, with the road winding up its rude and rocky side, formerly extremely dangerous; but was divested of its horrors some years ago by direction of Parliament: still, however, the traveller shudders; on creeping round the side of the mountain, he hangs as it were in mid air, with a frowning precipice above and a steep descent immediately under; the rocks to the right are nearly perpendicular, beetling over the road in a terrific manner, then retiring into deep declivities, 1000 feet in depth, from whose rugged sides project immense fragments, so capriciously placed, that the traveller may every moment expect to be crushed to atoms. The face of the mountain can never be cleared, or the danger entirely removed. The road from hence to Conway passes through one continued scene of rock and mountain till within about a mile of the town, when, by a turn to the right, a view of its neighbourhood, and the most sublime ruin in the kingdom, its magnificent castle, presents itself. This noble fortress was built by Edward the First, and comprised the whole of the present town within its yard; nothing can be more striking than its appearance at a short distance; the extent and substance of its walls, the number and hugeness of its round towers, erected on a rock, and rising sublimely above a noble estuary, produce an effect prodigiously grand. The exterior walls are about a mile and a half in circumference, and express the figure of the Welsh harp; the interior, though in a state of ruin, present many apartments; the great hall stands conspicuous, being 130 feet long, 32 broad, and of a proportionate height, whose former state the poet beautifully describes:—

> "Along the lofty window'd hall
> The story'd tapestry was hung:
> With minstrelsy the rafters rung."

Plate I. represents a view of the north side of the Menaï Bridge, and a plan of the roadways. The plan shows the division of the roadway into three parts; the middle part is a path, four feet in width, for foot passengers; and it has on each side a road 12 feet in width for carriages, horses, &c. The suspending cables are disposed in four lines, so that the foot path and carriage-roads are between them. On the right the bridge connects with the island of Anglesea; on the left with the county of Caernarvon.

OF THE

BRIDGE AT CONWAY,

IN THE COUNTY OF CAERNARVON.

THE committee of the House of Commons appointed to inquire into the state of the Chester and Holyhead road, found that great delays occurred in the arrival of the mails from Chester at Holyhead; which delay was principally owing to the bad state of the road through the principality, but still more so by the ferry at Conway, which was attended with serious inconvenience, much delay, occasional danger, and even actual loss of lives. To point out a remedy, they investigated two plans proposed by Mr. Rennie, who was of opinion, that no situation was so well adapted for the purposes of a bridge as the situation opposite the castle; but which he considered would be an expensive undertaking; the channel being wide, and great part of it of a loose shifting sand, reaching a considerable depth. Clay was expected to be found under the sand, but at a great depth. Application was made to Parliament, and a grant of 40,000*l.* obtained towards defraying the expense of erecting a suspension bridge, by which a great inconvenience would be removed. It has been decided in the Court of King's Bench, that coach passengers, with their luggage, have a right to be franked over by the proprietors. The established charges are, one penny for foot passengers; two pence for man and horse; and half a crown a wheel for carriages; but they have been known to charge half a guinea for ferrying over a gig, in addition to liquor: indeed, the numerous and unblushing impositions, long practised at this ferry, called loudly for investigation and amendment.

According to one of Mr. Rennie's designs, he proposed to build a bridge opposite to the east end of the castle, having its approach through the middle of the castle, which could easily be effected without injuring its beauty; and at the west end of the castle a bank of earth, to make the approach, either to the market place, or lower down, easy and convenient, for the town itself, as well as the public. At the east end of the castle he proposed to raise two towers, corresponding with those of the castle, to serve as an abutment; and four towers on the island, connected together by rubble walls; between these he proposed a cast-iron arch of three hundred and fifty feet span, and one hundred feet from the water at an ordinary spring-tide, to its crown, which was more than sufficient for the navigation of any vessel trading in that river. From the abutment on the island, a causeway of rubble stone, fifty feet broad at the top, and sloping about three to one on each side: this causeway was to be sunk in the sand four feet, and its top higher than low water-mark, the stones well rammed together, and guarded by sills with sheeting piles driven twenty feet into the sand, and connected by cross sills. This causeway was to extend as far as the deep water, about two hundred and thirty yards, and on it piers and twelve arches, and between the piers inverted arches, to equalize the weight of the structure; from the end of the causeway an embankment of earth to extend to the shore; the breadth of the road was to be thirty-two feet within the parapet. By this plan the strength of the tide would, in some respect, be confined to the Conway shore, but allowed to pass through the arching on the opposite side of the island, considerably below high water, consequently not likely to check the tide, or be injurious to the town of Conway. Another design of Mr. Rennie's was, to dispense with any stone arches, and continue the embankment to the island.

This last plan, in many respects, corresponds with the one proposed, and now carrying into execution, by Mr. Telford, which consists of one opening or suspension bridge, from the castle to the island, comprising a span of three hundred and fifty feet. The communication between the island and eastern shore is by an embankment of earth, cased with a thick coating of stones, which counteracts the operation of the tide upon the eastern embankment. The extent of this embankment, when finished, will be about three thousand feet, sloping gradually from the end of the bridge on the island to the east shore, and of sufficient width to accommodate carriages passing and repassing. The roadway of the bridge is suspended from cables, similar to the Menaï, carried over towers at the points of suspension. Here, however, there will be only one roadway, with foot paths on each side; in other respects the construction of this bridge, in minute particulars, so closely corresponds with the one over the Menaï, that a lengthened detail would be tedious and uninteresting. As there is but one roadway, the number of cables will not be so great as at Bangor; and in proportion as the span is less, the suspending powers required will be proportionably so. The pillars supporting the cables are about twenty-four feet high from the roadway, and the distance from high water-mark to the road way is about eighteen feet. The depth of water under the bridge at high water is generally from twenty-three to twenty-six feet, and at low water from twelve to fifteen feet; but although the strength of the tide is more generally confined to the Conway shore, yet so long as it is permitted to pass between the island and the eastern shore, the channel is continually shifting, and the water under the site of the bridge without any fixed criterion as to depth, which renders the navigation of the river difficult and uncertain; but when the present embankment reaches the island, and a considerable body of the tide is thereby checked in its present course, it is a matter of opinion, whether such check may not be of service to the navigation of the river, as well as to the town of Conway, as there is so great an extent of bay to fill by the making tide, and to empty at its return, that in all probability it will scour a deep channel under the bridge, between the castle and the island, and thereby improve the navigation. This great work is also under the management of Mr. Telford, and, when finished, will, no doubt, add another laurel to his justly acquired fame; but however great the object gained in completing this bridge, it is to be hoped the work of improvement will not stop here; for without a new line of road from hence to Aber, the principal object in view will be far from attained, as the present road from Conway to Aber is the most tedious and dangerous that can be conceived, and which might be effectually and without difficulty altogether, avoided, without any great increase of distance, by a line parallel with the beach the whole way. The utmost facility likewise presents itself, of greatly improving the line from hence to Abergele, and at a very moderate expense.

The banks of the Conway river afford the most diversified and romantic scenery. Mountains rising on every side, some thickly mantled with wood, others lifting their bare rocky heads into the clouds, a noble river rolling through extensive meads, clothed in luxuriant verdure, neat cottages, and sweetly secluded mansions—Marl, Bodscallen, Gloddiarth, and Dyganwary, appear conspicuous, with their fine woods decorating the declivity of the mountain to the eastward; Pennarth, the beautiful seat of Colonel Burroughs, on an eminence embosomed in wood to the westward; with the Bay of Conway at your feet: the whole combining finely to complete the picture.

THE view, in Plate II. represents the north side of Conway Bridge, and the magnificent ancient castle which adjoins it on the right. The place, on which the tower at the east end of the bridge is built, was a small island, but is now connected with the eastern shore by an embankment covered with rough or rubble stones to protect it from the action of the water. On this embankment is formed the roadway by which the bridge is approached from the east; and after passing the bridge the roadway continues to the west through the centre of Conway castle.

> "Proud pile! thy tempest-beaten towers still rear
> Their heads sublime, and to the angry storm
> Bid bold defiance; though their aged brows
> Bear visible the marks of strong decay."

T. G. Cumming del.ᵗ M. Dubourg sculp.ᵗ

AN ACCOUNT

OF VARIOUS

SUSPENSION BRIDGES;

PARTICULARLY OF

CAPT. S. BROWN'S,

NEAR BERWICK-UPON-TWEED.

The earliest bridges of suspension, of which we have any account, are those of China, said to be of great extent; and Major Rennel describes a bridge of this kind over the Sampoo in Hindostan, of about 600 feet in length; but the first chain bridge in our own country is supposed to be the Winch Bridge over the River Tees, forming a communication between the counties of York and Durham. This bridge is from rock to rock, over a chasm sixty feet deep, for the passage of travellers, but particularly of miners: the bridge is seventy feet in length, and only a little more than two feet broad; with a handrail on one side, and planked in such a manner that the traveller experiences all the tremulous motion of the chain, and sees himself suspended over a roaring gulf, or an agitated and restless gangway, to which few strangers dare trust themselves. This bridge was erected about the year 1741.

It appears that eight bridges have been erected upon the suspension principle in different parts of America, but none upon an extensive scale. The next bridge worthy of notice upon this principle was built by Mr. Lees, an extensive manufacturer at Galashiels, whose works are situate on both sides of the Gala water; he, therefore, conceived the idea of forming a foot bridge of slender iron wires, for the purpose of communicating readily with the different parts of his works: its extent is 111 feet, and cost about 40*l*, though only of a very temporary and imperfect construction; yet being the first wire bridge erected in Great Britain, it deserves particular notice, as affording a useful practical example of the tenacity of iron so applied, and its utility in many situations in an inland country, where the carriage of bulky materials is extremely expensive.

The next wire bridge was at King's Meadows, on the estate of Sir John Hay, Bart. This foot bridge is thrown across the Tweed, a little below Peebles; it is 110 feet in length, and four feet in breadth: it was executed by Messrs. Redpath and Brown, of Edinburgh, and cost about 160*l*.

A wire bridge was erected at Thirlstane, over the Etterick, by the Hon. Capt. Napier, of 125 feet span.

A chain bridge has also been erected at Dryburgh Abbey, of 260 feet in extent between the points of suspension, and four feet in breadth. It was executed by John and William Smith, builders, of Melrose, at the expense of the Earl of Buchan, as proprietor of the ferry, and cost his lordship about 720*l*. It is constructed for foot passengers and led horses.

The work which we next refer to, is the *Union Bridge across the River Tweed*, at Norham Ford, five miles from Berwick *. This work was completed in twelve months, whilst a stone bridge must have been the work of about three years. It was designed and executed by Capt. Samuel Brown, of the Royal Navy, who has so successfully introduced the use of the chain cable into the navy and mercantile marine. The roadway of this bold design is made of timber, on which iron cart tracks are laid for carriage wheels. It is eighteen feet in width, and 361 feet in length; the main beams, or joisting, measure fifteen inches in depth, and seven inches in thickness. The great platform is suspended at the height of twenty-seven feet above the surface of the summer water of the river: it is also made to rise about two feet in the centre, and is finished on each side with a cornice fifteen inches deep. The roadway is suspended from the main chains by circular rods: the main chains are twelve in number, ranged in pairs. The whole of the iron work is of the best Welsh iron; the chains are worked into a circular form; the links, as they may be termed, consist of rods fifteen feet in length, and have bolt holes strongly welded: these links are connected together by strong shackles. Though the timber road way is only about 361 feet in length, yet the chord line of the main chains measures no less than 432 feet between the points of suspension, with which they make an angle of about twelve degrees; the twelve main chains, with their apparatus, weigh about five tons each; and the weight of the whole bridge, between the points of suspension, is estimated at 100 tons. On the north side of the river the chains pass over a pillar of masonry, sixty feet high, thirty-six feet wide, and seventeen feet and a half in thickness: the ends of the main chains are made fast to ballast plates of cast iron, sunk twenty-four feet deep; the ends thus fixed are loaded with mound stones and earthy matter, to the level of the roadway of the bridge.

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* An elegant view and plan of this bridge may be had of the Publisher, size 26 inches by 12.

The general effect of this bridge is light and elegant, and not inaptly compared to an inverted rainbow. It is said, that the whole works of the Union Bridge, masonry, carpentry, and smithery, were undertaken by Capt. Brown, for 5000*l.* whilst the execution of a bridge of stone must have cost, at least, four times that sum. The object of its projector, however, does not appear to have been the realization even of the cost of this bridge; it was undertaken chiefly with a view to show the application of chain cables to his favourite object of bridge building; and it is hoped that his well-merited exertions will ultimately meet proper remuneration in the execution of other useful works. The trustees of this bridge, with proper liberality, have presented Capt. Brown with 1000 guineas since the completion of the work, over and above the estimated price.

The last great work I shall allude to upon this principle is, the proposed construction of a bridge over the Estuary of the Mersey at Runcorn Gap, about twenty miles from Liverpool, perhaps the most precarious and difficult problem ever presented to the consideration of a British engineer; it was the suggestion of some highly patriotic gentleman of Liverpool.

The specification for this work provided that the span of the bridge should measure, at least, 1000 feet, and that its height above the surface of the water should not be less than sixty feet, so as to admit of the free navigation of this great commercial river. The idea of a bridge at Runcorn, I believe, was first conceived about the year 1813, when the demand for labour was extremely low, and a vast number of the working classes of Lancashire were thrown out of employment.

A variety of designs for this bridge were procured by a select committee of the gentlemen who took an interest in this great undertaking. The plan most approved of, however, was the design of a bridge of suspension; and Mr. Telford, the engineer, and Captain Brown, of the royal navy, are understood pretty nearly to have concurred in opinion as to the practicability of such a work. Mr. Telford has reported fully on the subject, and has estimated the expense of his design at from 63,000*l.* to 85,000*l.* according to the different modes of execution. Though as yet little advancement has been made in carrying this enterprising design into execution, yet the novelty and magnitude of an arch of 1000 feet span is a subject of so much interest, that I have thought it proper, in this place, to mention these circumstances. Mr. Telford made a number of experiments, with a view to obtain the best data with respect to the strength of the materials proposed to be employed in this stupendous undertaking *.

Bars of iron were fixed at certain distances, with certain degrees of curvature, and weights hung upon them in the middle, and in different parts, until they broke.

Messrs. Brunton, of the iron cable manufactory, made various experiments on the strength of iron, with a hydraulic press, made on Bramah's principle, all of which led to the fullest confidence in the practicability and success of the undertaking †. From the nature of the navigation of this part of the Mersey, a bridge of three spans, or openings, has been projected: the centre span of 1000 feet, and the two others

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* These interesting experiments are fully detailed, and compared with theory, in Mr. Barlow's Essay on the Strength of Timber, &c. p. 241—254. Sec. Edit.

† See Barlow's Essay, p. 251, where they are described.

500 each, making the entire length 2000 feet: it will also be necessary to keep the lower side of the road-way eighty feet above high water-mark:—an arched bridge, under these circumstances, is conceived to be wholly impracticable.

In addition to the experiments before alluded to, the Runcorn bridge committee, for conducting the work, considered the undertaking of so much magnitude and novelty, that they made some personal experiments to the extent of the centre span; a sub-committee being selected, the experiment was tried over a valley near Liverpool, and the result not only confirmed, but far exceeded the calculations made by the engineers. Subscriptions to a considerable amount were immediately put down, but as yet no further steps have been taken.

After what has been stated, it is not necessary to observe that no danger is to be apprehended from the ordinary weight of any passing load; but in all projects of this kind it is proper and necessary to guard against extreme cases, by taking into consideration the crowded state of the road-way in the event of a drove of cattle, or number of people, passing; the latter of which is capable of inducing a greater weight, and, in certain cases, under less control, consequently more dangerous than the former; and it is clearly ascertained, that any given area, closely covered with men, will have greater weight than the same span occupied by cattle, in the proportion of nine to seven; besides, cattle are more likely to be gradually admitted on the road-way of a bridge than a mob of people, who are often attracted to one particular spot: but the effect most to be feared and provided against in bridges of suspension, is not merely what is termed dead weight, but what is more powerful, any sudden impulse or jerking motion of the load. Perhaps the greatest trial a bridge is subject to, is the passing of a regiment of foot, marching in regular time; a troop of cavalry does not produce corresponding effects, from the irregular step of the horses; the same with persons walking promiscuously, or a drove of cattle, which counteract the rocking motion. Violent gusts of wind may sometimes be considered dangerous, to guard against which various plans have been hit upon: having the road-way and side-rails framed in the strongest manner, is an important object. To what extent this mode of bridge building may be carried is at present very uncertain; at all events, we have been taught a speedy and convenient method of crossing rivers, ravines, &c.; and those who reflect upon the history and progress of the steam-engine may be led to conclude, that the purposes to which bridges of suspension may be applied are by no means exhausted.

THE END.

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